Simulating Performance Impacts of Bus Priority Measures

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***Abstract*- Public transport has an important role to play in the provision of reliable travel in congested conditions as it makes excellent use of limited road space, carrying many more passengers than a private car for a given amount of road space. This paper involves study and analysis of various Bus Priority Measures in terms of change in delay with respect to normal intersection for the buses and also for whole traffic flow (including buses and all other vehicles) with the help of results of VISSIM simulation software for various volumes of traffic flow. These measures can be applied to give buses priority to make them a more attractive alternative to the private vehicles and reducing road congestion.**

***Index Terms* - Bus Priority, Queue Jump Lane, Exclusive Bus Lane, Microscopic Simulation, Heterogeneous Traffic**

I. Introduction

The road network needs to move people and goods efficiently if we are to ensure the social and economic well-being of our communities. The capacity of our roads has not increased at anything like this rate and this has led to severe traffic congestion. This requires encouragement of public transport modes like buses. A bus may carry twenty times as many passengers as a car, yet it only contributes three times as much to congestion (CCMS, TRRL, UK, 1976). But due to large size of buses compared to other vehicles and increasing congestion buses cause delay and inconvenience which makes bus transit less appealing to passengers. This requires giving bus priority over other vehicles.

II. BUS PRIORITY MEASURES

Bus Priority Measures are techniques used to give buses priority over general traffic. Priority measures are the collective term used for a range of traffic management measures where the delays and unreliability to public transport caused by physical constraints and other vehicles are removed or significantly reduced. The major benefits of bus priority measures are: reduced delay due to elimination of friction between buses and other traffic, improved reliability and regularity of bus service, improved bus utilization, reduced bus operating cost, effective utilization of available road space and reduced accident rates. Some of the methods of bus priority which are discussed and studied in this paper are given below:

A. Double Queue Jump Lanes for Buses (Bus Priority1)

Along with rest of the traffic, buses spend significant time waiting on signals. A special lane on the curb side can help buses bypass the queues that build up before traffic signals. The special lanes, designed to make buses 'jump' the queue are called "Queue Jump Lanes" (QJL). It consists of an additional travel lane on the approach to a signalised intersection at around 150m before intersection. The intent of the lane is to allow the higher-capacity vehicles to cut to the front of the queue, reducing the delay caused by the signal and improving the operational efficiency of the transit system.

A queue jump lane is generally accompanied by a signal which provides a phase specifically for vehicles within the queue jump. Such a signal reduces the need for a designated receiving lane, as vehicles in the queue jump lane get a "head start" over other queued vehicles and can therefore merge into the regular travel lanes immediately beyond the signal. In case of queue jump lane for buses, left turning buses also have to wait for signal with other buses, so to overcome this problem, at the mouth of intersection before 150m of intersection one extra lane can be given to all left turning buses and out of remaining lanes one lane is provided to all other buses and other lanes are for all vehicles other than buses.

B. Exclusive Bus Lane Followed by Special Lane for Left Turning Buses at Intersection (Bus Priority 2)

To reduce the delay of bus and provide priority not only at the intersection but also on whole road, exclusive bus lane can be provided and also this can be followed by special lane for left turning buses at the mouth of intersection around 150m before intersection so that left turning buses need not to wait for green signal with right and straight going buses on exclusive bus lane.

C. Exclusive Bus Lane Followed by One Extra Lane for Vehicles Other than Buses at Intersection (Bus Priority 3)

To reduce the delay of bus and providing priority not only at the intersection but also at whole road, exclusive bus lane can be provided. But this method leads to much increase in delay for vehicles other than buses due to less number of lanes available for them at intersection. So as to compensate for this, buses coming through exclusive lane are continued

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to one special lane at mouth of intersection around 150m before intersection and all remaining lanes are provided to vehicles other than buses.

III. LITERATURE REVIEW

Bus priority schemes have been implemented in many urban areas around the world with the major objective underlying their implementation being to enhance bus attractiveness and improve its competitiveness with respect to other modes. Some of the common bus preferential treatments are provision of queue jump lanes and exclusive bus lanes on major urban roads, to facilitate faster movement of buses, which will make the mode more attractive. Methods of bus priority are not new as they have been used many times before and various researches have been made on them, some of them are mentioned below:

Tod et al. [1991] briefly discuss queue jump lanes, and the authors provide a transit vehicle time savings of between six and 29 seconds, with added delay to traffic of 0.3 to 2.9 seconds per vehicle. Mirabdal et al. [2002] documented the results of an actual queue jump implementation in San Francisco with a 38 percentage mean travel time reduction, and a travel time standard deviation reduction from 103 to 44 seconds. Cox (1975) studied the exclusive bus lanes that were implemented in the city of Dallas, Texas, USA. He concluded that the assignment of special lanes to buses had not adversely affected the level of service of the vehicular traffic, and there had been a reduction in travel time, a reduction in the number of stops, and an increase in speed of buses. Also, the improved level of service of bus transit, due to bus lane implementation, had attracted additional ridership.

Vedagiri and Arasan (2009) estimated the probable shift of car users to bus due to increase in its level of service after providing exclusive bus lanes on Indian city roads carrying heterogeneous traffic. The quantum of increase in level of service of bus due to introduction of exclusive bus lane was determined using simulation model of heterogeneous traffic flow. This paper identified consequent on the increase in the level of service of buses, to explain the variation in shift behaviour of personal vehicle users to buses.

It is clear from the review of literature that the most of reported studies have been conducted under fairly homogeneous traffic conditions and there are no ready-to-apply reference materials available to assist in bus priority measures planning and design under heterogeneous traffic conditions, in which different types of vehicles share the same road space without any physical segregation. Hence, there is a need to devise appropriate methodology to study the effect of bus priority measures on heterogeneous traffic flow. Also most of these studies concern only exclusive bus lanes and queue jump lanes. But depending upon the various traffic conditions like heterogeneity, tuning proportion, traffic composition, availability of space and many other factors, these methods may not be that much effective. So there is need to study more and find wide range of methods which can be applied to gain better results.

IV. OBJECTIVE

The specific objectives of this paper are as follows:

- To study various possible methods to provide bus priority under heterogeneous traffic conditions which can be better in terms of results like delay reduction
- To analyse all these methods in terms of change in delay with respect to normal intersection for the buses and also whole traffic flow with the help of VISSIM simulation software for various volumes of traffic flow
- To compare all these methods and rank them on the basis of efficiency in terms of delay reduction and suitability in Indian traffic conditions.

V. STUDY METHODOLOGY

The proposed designs are tested using VISSIM simulation software by conducting experiments. Normal intersection is compared with all the three Bus Priority Methods in terms of average delay of buses and other vehicles. VISSIM is a microscopic multi-modal traffic flow simulation software. “Microscopic simulation” sometimes called micro-simulation, means that each entity (car, train, person) of reality that is to be simulated is simulated individually, i.e. it is represented by a corresponding entity in the simulation, thereby considering all relevant properties. The same holds for the interactions between the entities. The opposite would be a “macroscopic simulation”, in which the description of reality is shifted from individuals to “averaged” variables like flow and density. The experiments were conducted for different traffic volumes varying from 1000 vehicles per hour to 3500 vehicles per hour. The VISSIM software enable us to simulate the design and gives results according to the given parameters. The lane width for every road is 3.5m and the traffic behaviour is set according to the heterogeneous and random traffic in India. This enables us to approximate the results to utmost accuracy. It will give us the average delay of all vehicles at the intersection in both the cases Normal Intersection and Bus Priority Method which makes it easier and convenient for comparison. The snapshot for one of the methods is shown below in figure: 1 for bus priority 1.

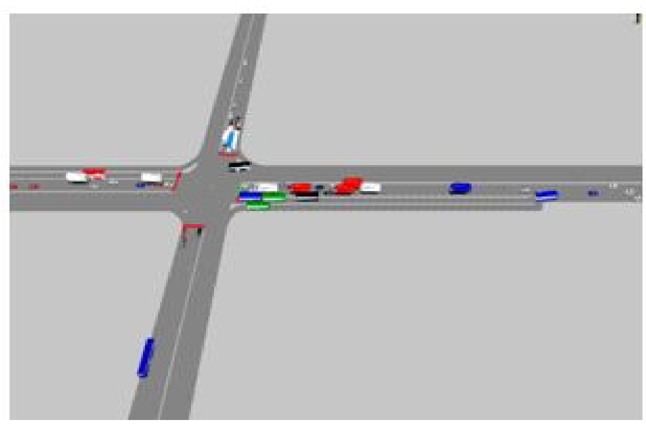

Figure 1. VISSIM Snapshot for Bus Priority 1

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VI. Model Validation

Validation is the overall process of comparing the model and its behaviour to the real system and its behaviour (Banks et al., 2004) [4]. In particular, Law and Kelton (1991) point out that if the two sets of output data compare "favourably," then the model of the existing system is considered "valid" [5]. The Bhagwan Mahavir Chowk in Vashi, Navi Mumbai is used as study intersection. A VISSIM model was made to simulate these conditions and validate the model for further analysis. Simulation run time was set as 3600 seconds to replicate the real conditions. Total number of vehicles in the network during the period of survey is 5017. Average queue length in the approach A is 56 m. The total number of vehicles in the network as obtained for the data collection points provided in the 4-Arms was found to be 4775. For any validation to be accurate the error obtained between the simulated and the real data should not be greater than 10%. We obtain an error of just 4.82% in this case. The simulated result for the queue in the approach arm A is 60m while the observed queue length was 56m. Therefore the error is 7.14%. Since both the validation criteria are met with relatively high accuracy, the VISSIM model of Bhagwan Mahavir Chowk can be regarded as a true representation of the real system. Therefore the model can be used for further analysis and experimentation.

VII. Simulation Experiment

While experimenting, total cycle time taken for normal intersection is 120 seconds and whole network is divided in four phases. Two phases each of 40 seconds are for major roads and remaining two phases of 20 seconds each are for minor roads. And while experimenting total cycle time taken for bus priority method is 120 seconds and whole network is divided in six phases. Two phases each of 25 seconds are for major roads and two phases each of 15 seconds are for bus priority lanes and remaining two phases each of 20 seconds are for minor roads. Amber time used is 2 seconds in both the cases. Depending upon the characteristic of traffic, different type of composition and turning proportion can be used for the analysis of delay. Out of four arms of road, two arms are considered major and two are considered minor. Bus Priority Measures are applied for the major road. Volume of traffic considered for minor road is half of the volume for major road. Turning Proportion is considered as 50% of the vehicles straight going, 30% right turning and 20% is left turning. Traffic composition which is heterogeneous in nature is given below in figure: 2

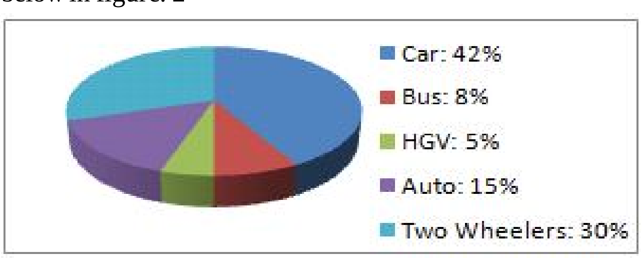

Figure 2. Traffic Composition

All of these three methods are analysed for average delay of buses and whole traffic flow on overall network, results are than compared with that of normal intersection in terms of delay reduction. Number of lanes for Normal intersection is three on both major and minor roads in all cases.

A. Double Queue Jump Lanes for Buses (Bus Priority1)

Number of lanes are 3 for both major and minor roads. This method provides priority only at the intersection. Number of lanes is increased from 3 to 4 around 150m before the intersection on approach coming towards the intersection on major road. Out of these four lanes 1 lane is provided to left turning buses for free left turn. One lane is provided to right and straight going buses and separate signal phase is given to this lane. Remaining 2 lanes are for all other vehicles. Diagram for flow of traffic is shown in Figure 3.

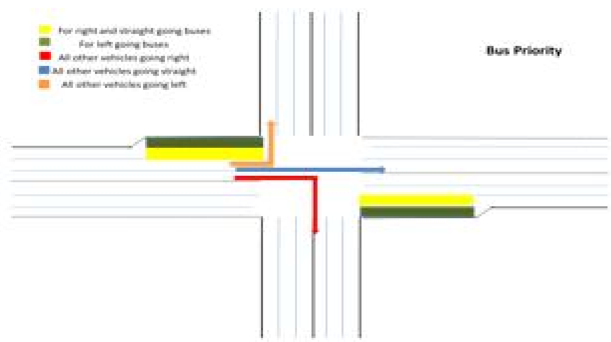

Figure 3. Flow Diagram (Bus Priority 1)

B. Exclusive Bus Lane Followed by Special Lane for Left Turning Buses at Intersection (Bus Priority 2)

Number of lanes are 3 for both major and minor roads**.** In this method, we have provided priority not only at the mouth of intersection but for whole length of road. For whole length of road one lane is provided exclusively to buses and other two lanes are for all other vehicles. Number of lanes is increased from 3 to 4 around 150m before the intersection on approach coming towards the intersection on major road. Left turning buses on exclusive bus lane now uses this extra lane for free left turn. Right and straight going buses uses the same exclusive bus lane and separate signal phase is given to this lane. Remaining 2 lanes are for all other vehicles. Diagram for flow of traffic is shown in Figure 4.

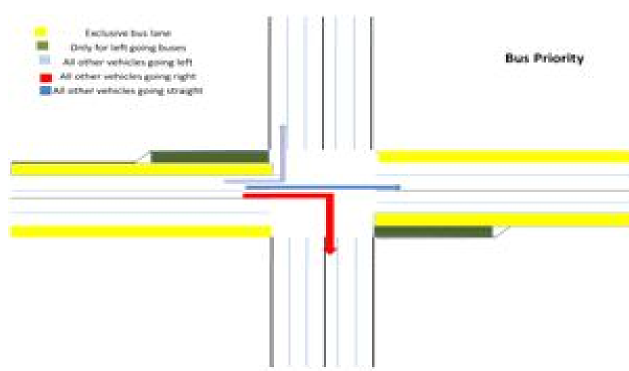

Figure 4. Flow Diagram (Bus Priority 2)

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C. Exclusive Bus Lane Followed by One Extra Lane for Vehicles Other than Buses at Intersection (Bus Priority 3)

Number of lanes are 3 for both major and minor roads. In this method also, we have provided priority not only at the mouth of intersection but for whole length of road. For whole length of road one lane is provided exclusively to buses and other two lanes are for all other vehicles.Number of lanes is increased from 3 to 4 around 150m before the intersection on approach coming towards the intersection on major road. All buses on exclusive bus lane now use this extra lane for crossing the intersection and separate signal phase is given to this lane. Remaining 3 lanes are for all other vehicles. Diagram for flow of traffic is shown in Figure 5.

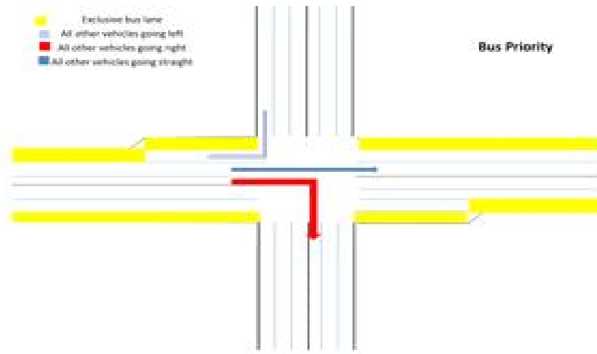

Figure 5. Flow Diagram (Bus Priority 3)

All of these 3 methods are now analysed with the help of VISSIM Simulation Software and results are tabulated in Table I, Table II and Table III for Bus Priority 1, 2 and 3 respectively.

TABLE I. Average Delay for Buses and Whole Traffic Flow for Bus Priority 1

Traffic Volume on major road (in vehicles per hour)	Average Delay for whole traffic flow on complete network (in seconds)		Percentage change in average delay for whole traffic flow	Average Delay Only for Buses on complete network (in seconds)		Percentage change in average delay for Bus Only
	Normal	Bus Priority		Normal	Bus Priority	
1000	42.30	44.09	+4.25%	54.91	48.71	-0.11%
1500	53.03	65.18	+22.90%	68.66	57.60	-16.10%
2000	82.96	117.19	+41.24%	101.27	81.22	-19.79%
2500	157.53	156.61	-0.584%	170.17	132.62	-22.06%
3000	217.52	186.77	-14.13%	229.84	173.42	-24.54%
3500	261.75	219.08	-16.30%	275.16	197.84	-28.10%

TABLE II. Average Delay for Buses and Whole Traffic Flow for Bus Priority 2

Traffic Volume on major road (in vehicles per hour)	Average Delay for whole traffic flow on complete network (in seconds)		Percentage change in average delay for whole traffic flow	Average Delay Only for Buses on complete network (in seconds)		Percentage change in average delay for Bus Only
	Normal	Bus Priority		Normal	Bus Priority	
1000	42.30	43.16	+2.04%	54.91	46.24	-15.78%
1500	53.03	52.88	-0.279%	68.66	51.59	-24.86%
2000	82.96	106.72	+28.62%	101.27	65.09	-35.72%
2500	157.53	143.24	-9.07%	170.17	83.92	-50.68%
3000	217.52	167.33	-23.07%	229.84	100.29	-56.36%
3500	261.75	187.61	-28.32%	275.16	122.32	-55.54%

TABLE III. Average Delay for Buses and Whole Traffic Flow for Bus Priority 3

Traffic Volume on major road (in vehicles per hour)	Average Delay for whole traffic flow on complete network (in seconds)		Percentage change in average delay for whole traffic flow	Average Delay Only for Buses on complete network (in seconds)		Percentage change in average delay for Bus Only
	Normal	Bus Priority		Normal	Bus Priority	
1000	42.30	41.12	-2.78%	54.91	58.89	+7.25%
1500	53.03	46.79	-11.76%	68.66	71.07	+3.50%
2000	82.96	62.01	-25.25%	101.27	90.15	-10.97%
2500	157.53	102.07	-35.20%	170.17	143.56	-15.63%
3000	217.52	143.08	-34.22%	229.84	173.03	-24.71%
3500	261.75	176.52	-32.56%	275.16	181.53	-34.02%

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VIII. RESULTS

Simulation results for bus priority 1 shows that this method has led to decrease in delay of buses for whole range of traffic volume. This varies from 0.11% delay reduction for 1000 vehicles per hour to 28.10% delay reduction for 3500 vehicles per hour. Simulation results for bus priority 2 shows that this method has led to decrease in delay of buses for whole range of traffic volume. This varies from 15.78% delay reduction for 1000 vehicles per hour to 55.54% delay reduction for 3500 vehicles per hour. Simulation results for bus priority 3 shows that this method has led to decrease in delay of buses for whole range of traffic volume except for the case of small traffic volume of 1000 and 1500 vehicles per hour. For these cases delay for buses is increased slightly by 7.25% and 3.50% respectively. For higher traffic volume it has varied from 10.97% delay reduction for 2000 vehicles per hour to 34.02% delay reduction for 3500 vehicles per hour.If results are observed for overall traffic flow all of these methods have shown good results for higher traffic volume. Method 3 has resulted in decrease of delay for whole traffic flow for all volumes as it involves priority for vehicles other than bus also, but in case of method 1 and 2 results are not good for whole traffic flow in initial volumes which is expected as number of lanes for vehicles other than buses is only 2 at the mouth of intersection. But for higher volume it is compensated by high reduction in delay for buses. Results for buses are better in method 2 and 3 as compared to 1 as these methods involve priority for whole length of road but method 2 involves priority only at the mouth of intersection.

So far we observed results of each experiment individually, now we have to compare effectiveness of all of these methods. We see that all of these methods are found to be more effective for higher traffic volumes. So it is better to compare them on the results of higher traffic volumes. For instance, compare them for the percentage change in delay for traffic volume of 3500 vehicles/hour. Corresponding comparison is tabulated in table IV.

TABLE IV. AVERAGE PERCENTAGE REDUCTION IN DELAY FOR CONGESTED TRAFFIC

Bus Priority Type	Average of Percentage Reduction in Delay of whole Traffic Flow		Average of Percentage Reduction in Delay of buses	
Bus Priority 1	16.30	Rank 3	28.10	Rank 3
Bus Priority 2	28.32	Rank 2	55.54	Rank 1
Bus Priority 3	32.56	Rank 1	34.02	Rank 2

Bus Priority 2 is showing heavy reduction in delay of buses which is expected as it provides priority to buses for whole length of road and also more priority at mouth of intersection which helps buses to cross the intersection very efficiently. Bus Priority 3 is showing comparable results both for buses and whole traffic flow. This method which provides priority to buses for length of road is different from simple Exclusive Bus Lane Method as it compensates delay of vehicles other than buses by providing them one extra lane at the mouth of intersection. Bus Priority 2 and 3 involves providing priority for whole length of road which is not possible in all cases, but Bus Priority 1 involves priority only at mouth of intersection which can be done by making changes only at intersection.

CONCLUSIONS

Methods of Bus Priority which are described in this paper may have been used in some or another form in some parts of the world already. But this time these are visualised with respect to Indian heterogeneous traffic conditions. These methods are analysed with the help of Vissim Simulation Software and validated against the actual intersection. Now after experimenting and analysing all the proposed methods, we can see that all of these methods are found to be efficient for reducing the delay not only for buses but also for whole traffic flow, especially for the cases of higher heterogeneous traffic flow.

The results which we are getting in this experiment are for a particular traffic characteristics but this may vary according to variation in traffic characteristics like traffic composition, turning proportion etc. So any of these methods can show more effective results and can be used for reducing congestion on roads and decreasing the delay on the basis of traffic conditions prevailing and other parameters like space availability etc. It would not only reduce the road congestion but also help in terms of environment and fuel. This much effectiveness of these methods for providing priority to buses would encourage people to use buses instead of their private vehicles, which would reduce road congestion, result in large traffic flow and less pollution and noise.

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